Express Mail No. EV178025277US

PATENT APPLICATION OF

HAROLD E. HAMILTON
and
CHAD M. CONROY

ENTITLED

COOLING AIR FLOW CONTROL VALVE FOR BURN-IN SYSTEM

Docket No. M366.12-0027

COOLING AIR FLOW CONTROL VALVE FOR BURN-IN SYSTEM

BACKGROUND OF THE INVENTION

The present invention relates to apparatus for controlling temperatures of integrated circuit chips being tested on burn-in-boards in a burn-in oven or system. More particularly, the invention relates to a flow control valve that controls the flow of cooling air onto an associated heat sink for a circuit chip supported directly below the valve. The temperature of each integrated circuit chip is sensed and compared with a desired set point temperature to determine a temperature error signal and the amount of cooling air directed toward the heat sinks is varied as a function of the error signal to maintain precise temperature control.

Burn-in-ovens that are used for testing integrated circuits are well known. The prior art ovens have used various types of cooling devices for controlling the temperatures of the burn-in-boards within a selected range. Individual fans for providing cooling air directly on heat sinks, are shown in co-pending U.S. Application Serial No. 10/020,348, filed December 12, 2001. The fans work well but do not provide the cooling capability of the present invention. A more passive way of controlling the heat has been to provide a flow of air from plenum chambers at the ends of an oven across a

number of the chips supported on burn-in-boards and then exhausting the air out through exhaust panels.

The power required for testing has increased with the advent of circuits that consume more power in use. The ability to provide an adequate amount of cooling to each individual high power circuit under test to regulate the cooling and thus the temperature of each chip within acceptable limits has become more difficult.

The need for an easily controlled, highly responsive cooling airflow control continues to exist.

SUMMARY OF THE INVENTION

The present invention relates to a cooling airflow control system for a burn-in-board oven or enclosure that uses individual valves for controlling flow from a plenum chamber having a supply of cooling air onto one of the circuits, and in particular, onto a heat sink that is provided as part of a holder for the circuit chips for transferring heat away from the circuit. The valves are over openings in a tray, with each tray above a burn-in board. The heat sinks have radiating fins thereon and the cooling airflows help to dissipate the heat generated by the circuit devices under test, sometimes called DUTs.

The plenum chamber which forms an air supply for the valves is preferably, and as shown, an individual plenum chamber for each tray of valves used in the burn-in-oven. As will be shown, the

valve trays are spaced so a burn-in-board with DUTs can be placed below each valve tray.

Each holder for the DUTs includes a temperature sensor that senses the temperature of the circuit chip and provides a signal to a control computer or processor. A temperature sensor may also be embedded in the DUT for the same purpose. The processor compares the sensed temperature with a desired set point temperature to develop an error signal if there is the need for more or less cooling air. This error signal is used for controlling the valves of the present invention as desired.

In the present invention, the temperature differential signal, or error signal, is used for controlling the opening of individual valves that are positioned on a valve tray spaced from and above the individual circuits supported on a burn-in-board. The valve tray is a solid wall tray or plate spanning the burn-in oven and supported on rails in the oven, and has openings through which a valve controls air flow.

A cooling air plenum chamber is formed above each of the valve trays a shown, and preferably by using a solid wall panel overlying the respective valve tray supported on three sides of the tray to form plenum chambers with one side forming an inlet slot. There is a cooling air inlet opening at one end of the oven for each cooling air plenum chamber that is open to the inlet slot when the valve tray assembly is installed. The exit or exhaust passage

for air from the cooling air chamber is through the valves and corresponding openings in the tray to a heat sink chamber formed below the valve trays and above the respective underlying burn-in-board. The heat sinks are each in contact with a DUT to conduct heat away from the DUT.

The valve trays and burn-in-boards in the oven are alternated and stacked with spaces between the trays and boards so that the cooling air space or chamber above the valve tray may also be formed by another overlying burn-in-board. With any desired cooling air chamber above a valve tray, when a valve is opened, cooling air flows into the heat sink or heat exchange chamber between the valve tray and underlying burn-in-board and directly onto the heat sink below that valve. When all of the valves on a valve tray are closed, no cooling air flows onto the heat sinks for DUTS on the burn-in-board below the valve tray.

In use, the burn-in-oven will always have a full complement of valve tray assemblies, and may not have burn-in-boards under each valve tray assembly. If no burn-in-board is below a valve tray, the valves in such tray are left closed.

As shown, a conventional cooling air system is adapted to the desired oven configuration. An exhaust chamber receives air from each of the exhaust passageways for air from the heat sink chamber above the burn-in-boards after the air has been passed over

the heat sinks for the individual circuits. The air exhausted from the heat sink chambers circulates through an air cooler and then is forced back to the air supply by a blower or fan.

The valves are individually controlled and provide for better modulation of flow. Since barrel valves can adjust the flow through valve openings more precisely than other types of valves in use, such as butterfly valves, barrel valves are preferred, but other controllable valves will work.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a schematic side view of a burn-in oven showing a plurality of valve tray assemblies and burn-in-boards stacked vertically;

Figure 2 is a perspective view of the burn-in oven of Figure 1 showing only a few burn-in-boards and valve tray assemblies in position;

Figure 3 is an enlarged sectional view taken on line 3--3 in Figure 1;

Figure 4 is a fragmentary sectional view taken on line 4--4 in Figure 3;

Figure 5 is a fragmentary, schematic sectional view taken on line 5--5 in Figure 4;

Figure 6 is a perspective view of a valve tray positioned in a burn-in oven showing the valves in position on a valve tray;

Figure 7 is a top plan view of a barrel valve used in the present invention;

Figure 8 is a perspective view of a barrel valve shown in Figure 7;

Figure 9 is an exploded view of a barrel valve as shown in Figure 8;

Figure 10 is a sectional view of a typical barrel valve taken on line 10--10 in Figure 4; and

Figure 11 is a block diagram of a control system for the valves.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

A typical burn-in oven 10, shown schematically, is provided with a frame 12 that has four corner posts 13, held together as desired and supporting a series of rails or guides 14 for holding burn-in-board trays, and guides 16 for holding valve trays or boards made according to the present invention. The burn-in-board trays (also just called burn-in-boards) shown generally at 20 will slide in on the rails 14, and completely fill the area between the side guides and the walls defined by the frame 12, so that the burn-in-boards block airflow vertically in the oven enclosure. Insulated side walls and a door enclose the oven or other enclosure for testing.

Individual air flow control valve tray assemblies made according to the present invention includes trays or boards shown generally at 22 and specifically numbered 22A, 22B, 22C, and 22D in Figure 3, and these would be 22N valve tray assemblies in a burn-in oven. The valve trays slide

into the rails 16 and likewise will completely block the open horizontal area in the frame 12. As perhaps best seen in Figures 3, 4, and 5, each valve tray 22A-22D has an overlying solid wall 23A-23D spaced therefrom to form a cooling air plenum chamber 26A-26D, up to 26N plenum chambers. Each wall 23A-23D is supported on solid edge walls 25 on three sides of the respective tray leaving one side of the cooling air plenum chamber open with an inlet slot 27.

The cooling air plenum chambers 26A-26N of respective valve trays 22A-22N are above the valve trays and each valve tray 22A-22N is above an associated burn-in-board.

The space between the lower side of a valve tray and the underlying burn-in-board forms a heat sink chamber or heat exchange chamber. A first heat sink chamber 24 is formed above burn-in-board tray 20. A further valve tray 22B is positioned above the burn-in-board 20B, to form a heat sink chamber 24A above the burn-in-board 28B, and each subsequent burn-in-board 20 has an overlying valve tray 22 for a total 20N burn-in-boards, and 22N valve trays that form heat sink or heat chambers 24N stacked vertically.

The valve tray assembly a second cooling air plenum chamber 26B above the valve tray 22B is formed by walls 23 and 25. The stacked valve trays and overlying burn-in-boards form "26N" cooling air plenum chambers.

The cooling air is provided by a suitable fan or blower 28 that is coupled to a main cool air supply chamber shown schematically at 30 on one side of the oven 10. The cool air supply chamber 30 is open to the end inlet slots 27A-27D (up to 27N) of each of the cooling air chambers 26A-26N that are formed above the stacked burn-in-boards 22N. Only a few burn-in-boards and valve trays are shown for sake of simplicity in illustration, but they can be stacked vertically in as many of the slides or rails 14 and 16, as desired. Again, all of the positions for valve tray assemblies in the oven are filled, but if desired, only a selected number of burn-in-board trays are in the oven.

Cooling airflow is provided from the main cool air supply chamber 30 through slots or openings 32A-32D (up to 32N) through the side wall of the oven, and are shown schematically in Figure 2, and in Figure 4. The slots 32A-32N in the oven wall align with the cooling air plenum chamber inlet slots 27A-27D at the ends of the cooling air plenum chambers 26N formed by the valve trays 22, and walls 23 and 25. The cooling air plenum chamber of all of the valve tray assemblies are provided with cooling airflow from the main cool air supply chamber 30 through the slots 32A-32N.

On the side of the oven enclosure opposite from the main cool air supply chamber 30 for cooling air, there are exhaust discharge slots or openings

34A and 34B (Figure 2) (up to 34N), that align with the heat sink or heat exchange chambers 24 formed above each burn-in-board and below the respective overlying valve tray. There is an exhaust slot or opening for each of the heat sink or heat exchange chambers 24 formed by the respective burn-in-boards and the overlying valve trays. Exhaust openings are only from the heat exchange chambers 24-24N and lead into an exhaust chamber 21 in which an air circulation blower or fan 28 can be mounted.

The cooling air plenum chambers 26N above each of the valve trays have the inlet slots 27N at one end, but no constantly open exhaust openings. Cooling air is exhausted from plenum chambers 26 by passing through valves 40 that control flow into the heat exchange chambers 24-24N through openings 58 in the valve tray. However, some air will bleed out along the tracks or rails for the trays, and in order to provide some cooling air along the bottom surfaces of the burn-in-boards, a gap shown at 35 in Figure 4 permits some cooling air to enter the space above each wall 23 and below the overlying burn-in-board.

The cooling air for the main cool air supply chamber 30 is circulated by fan or blower 28 through an air cooler 42 in the flow path to exhaust air chamber 21, so that the air in the cool air supply 30 is cooled and is used for maintaining and reducing the temperature of the individual circuits.

Each of the circuits or devices under test (DUT) is supported in a socket or holder 44, that comprises a finned heat exchanger or heat sink, generally formed as shown in U.S. Patent Application Serial No. 10/646,889, filed January 14, 2002, and incorporated by reference. Each of the holders for the DUTs has a heater 45 and temperature sensor indicated schematically at 46 in Figure 4 and also in Figure 11. The temperature signal from the temperature sensor 46 is fed to a controller 48 (Figure 11), and the controller in turn is connected to the valves 40 to control the amount of opening of each valve. The burn-in-boards have connectors 47 at ends that extend out from one wall of the burn-in oven, as shown in Figures 3 and 5.

Figure 6 shows a typical valve tray assembly 21 and the valves 40 are shown in position on a tray 22. The valves 40 are preferably barrel valves as shown that have valve bodies 60 housing rotary valve elements 76 controlled by suitable motors 96. (See Figures 7-10 as well.) The motors 96 for two valves 40 are positioned side by side with the valve bodies 60 extending in opposite directions. The cooling airflow direction is indicated by the arrow 52 in Figure 6. The valves 40 are positioned at a slight angle to the orthogonal direction of airflow through the plenum chambers 26 and across the associated valve tray 22. The valve tray 22 may have rails 54 on opposite sides thereof that are used for

supporting it in the guides 16 of the burn-in oven 10.

As can be seen, the typical valve tray 22 has a plurality of individual barrel valves 40. Each of the valves 40 is mounted over an opening 58 (Figures 4 and 5) through the valve tray 22 so that flow controlled by the valve will be directed onto a finned heat sink or heat exchanger comprising the holder for the DUT on the burn-in-board directly below the respective valve 40.

Referring to Figure 7, a top plan view of a typical preferred valve 40 is illustrated. Also, Figures 8-10 are referred to for showing the different parts of the valves.

While barrel valves are preferred, and are illustrated as a best mode, other controllable valves can be used. Slide valves, rotary or pivoting cover valves, poppet valves and the like, which are capable of being opened and closed as a function of a control signal will work.

Each of the preferred form of valves 40 is provided with a valve body 60 that is made in two stacked sections 60A and 60B (see Figure 9). When the two sections are assembled, the housing has end walls 62 and 64, joined by side walls 66 and 68. The side walls 66 and 68 are spaced apart to form a top opening 70, and a bottom opening 72 as shown in Figure 10. Figure 10 includes a partial cross-section of the valve tray 22A. It shows that the valve tray

22A has openings 58 directly below the valve lower opening 72 so that there is an alignment for flow between the cooling air plenum chamber 26N above the respective valve tray 22A to the heat sink or heat exchange chamber 24N below the valve tray 22A.

The valve 40 has a rotary barrel valve element 76 that has mounting shafts 78 on both ends. The shafts 78 are rotatably mounted in suitable supports 80 on the end walls 62 and 64 of the valve body.

Each of the valve body sections 60A and 60B includes a portion of the end walls and the side walls formed to define the openings 72 and 70. The barrel valve element 76 is a part of a cylinder with parallel planar surfaces through which a central opening or passageway 88 is formed. The opening or passageway 88 is divided into four sections with transverse flow straightener walls 90. The opening or passageway 88 goes all the way through the part cylindrical valve element 76, as can be seen. The part cylindrical outer surface portions of the valve element 76 are along the top as indicated at 92. These part cylindrical surfaces extend between the parallel planar surfaces.

The side surfaces of the valve element opening in the valve body mate with the part cylindrical surface of the valve element 76. As can be seen in Figure 9, the lower housing section 82 has part cylindrical surfaces 94, and the upper section

has similar surfaces. The surfaces 94 seal with the outer part-cylindrical surfaces of the rotary or barrel valve element 76.

The mating part-cylindrical surfaces are such that they will continue to seal as the barrel valve element rotates 76. The valve element 76 has planar side surfaces, as can be seen. The sealing will continue as the barrel valve element 76 is rotated.

The valve element 76 of each valve 40 is driven by a separate motor 96 that is connected to a suitable source of power through the controller 48 (Figure 11). Connections to the motors 96 are made at connector ends 97 of the valve trays, as shown in Figures 3 and 6. The direction and amount of rotation of the output shaft 98 of each motor 96 will be determined by the controller in relation to the amount of air flow through the opening in the valve 40 onto the underlying heat sink that is called for by the sensed temperature differential signals between the sensed temperature at the DUT and the set point or reference temperature. Each valve motor can be controlled by a PID controller 48A which forms part of the main controller 48 again, as shown in Figure 11. The valve motors can drive other types of controllable valve elements, as explained.

The direction of rotation of the valve element 76 can be reversed by the motor 96. Barrel valves can control the flow more precisely than a

butterfly valve, for example, because the rotation of the barrel valve elements will proportionally open the flow path between a fully closed position and a fully open position.

It can be seen at Figures 8 and 9 that the associated motor 96 mounts directly onto the end of the body 60 for the barrel valve element 76, and makes a very compact package. Also it can be seen at Figure 5 that the valves 40 are arranged in pairs, with the motors 96 overlapping, and the valve bodies then extend from the motors in opposite directions to overlie openings 58 in the valve tray 22N.

Figure 11 is a simplified block diagram of the controller 48 and components and functions controlled. The heater 45 can be used to aid in controlling the temperature of the DUT. The controller also can control the temperature of the air heat exchanger 42 used to cool the supply air with a suitable refrigeration unit. The block 44 in Figure 11 is used to represent the complete holder, including the heat sink and the DUT.

Use of the individual valves permits much better control of airflow for cooling relative to the heat sinks than can be achieved with other forms and very precise and high temperatures can be controlled with this arrangement.

While the preferred embodiment shown provides a separate cooling air plenum chamber formed above each valve tray, when a burn-in-board is in

place above a valve tray, the overlying burn-in-board will form a cooling air plenum above the valve tray.

If all of the burn-in-board trays are installed in an oven, the separate walls forming the cooling air plenums above the valve trays can be omitted.

The valve trays or boards are relatively low cost, easily installed, and will provide for a direct, very controlled airflow path across the heat sinks on circuits being tested or burned in.

Although the present invention has been described with reference to preferred embodiments, workers skilled in the art will recognize that changes may be made in form and detail without departing from the spirit and scope of the invention.